Agents enacting social roles: balancing formal structure and practical rationality in MAS design

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1 Introduction

Sociologist Pierre Bourdieu pointed out the subtle and often ignored difference between theoretical rationality and the "logic of practice" [8]. This difference, we will argue, has to be taken in account when trying to capture the robustness and flexibility of human organizations, and is especially important for any effort to model information systems on mechanisms of organizational coordination. In the INKA-Project[1], part of the German Socionics program, we took this insight as our very starting point. Computational agents that "act" and coordinate themselves in a way that at least mimics in principle human actors in organizational environments have to cope with the tension between the formal descriptions given by the organization at large and the structured expectations that derive from their daily interactions on the shop-floor level. In sociology one way of conceptualizing this tension is role theory, focusing on the different forms of enactment of formal role descriptions and practical roles. Furthermore, from organizational theory and empirical investigations we know that in the 'real world' daily negotiations by the employees themselves are one way of working around the incoherences of formal prescriptions, job descriptions and work schedules. Based on these considerations the INKA-project is oriented by two main objectives: To model and implement a technical system in which the agents are capable of coordinating themselves via negotiating on the basis of practical roles, and to develop an approach for the investigation of hybrid sociality that emerges if those agents are re-entered into human organizations.

Our contribution begins with a brief discussion of the conceptual problems that occur if computer programs are to be modeled on practical relations or on sociological concepts of practical modes of interaction, problem solving and planning; this leads us to the formulation of three general challenges within the Socionics program (2.). In the next part we introduce in some detail our sociologically grounded modeling of practical roles and negotiating agents (3.), and our framework for a corresponding MAS-architecture (4.). Then we turn to two general issues, that came up at the present state of development in our project - and, as we assume, in the entire Socionics program. We propose an integrated approach that correlates all activities in Socionic systems development in a systematic way (5.), and we present a methodological instrument for the investigation of hybridization (6.). We conclude by sketching some conceptual extensions and further working steps (7.).

2 Practical Rationality: A Threefold Challenge within the Socionics Program

Human organizations offer an effective way of coordinating individual behavior while at the same time remaining capable of flexible adaptation to changing environments (cf. [2]). Concepts and theories from the sociology of organizations are thus perceived as an promising blueprint for the design of innovative information systems, especially in the realm of multiagent systems (MAS) research, where computational functionality is gained from the coordination of autonomous software entities. Moreover, human organizations, unlike many other social entities, tend to work out an

[1] The acronym INKA stands for "INtegreation of Cooperating Agents in complex organizations" and is carried out by the department of Artificial Intelligence at Humboldt University Berlin (Prof. H. -D. Burkhard) and the department for Technology Studies at Technical University Berlin (Prof. W. Rammert); see cf. [10].

explicit description of their own coordination principles - rules for membership, planing schedules, job descriptions adjusted to the internal division of labor, hierarchical chains of prescription and control, and so forth. These self-descriptions, often provided by management units, typically present a formally coherent and encompassing picture of the organization's functioning. This theoretically purified picture resembles the notion of formal rationality in Weberian sociology and in rational choice-approaches (cf. [29]). So at a first glance it might seem to be quite easy to model information systems on principles of organizational coordination.

Revisiting the iron cage, however, weakened and even contested this notion of a consistent body of formal rules and regulations. The findings of empirical investigations in the 'real life' of organizations pointed to a picture of "organized anarchies" ([12]), because formalized descriptions turned out to be inconsistent and often conflicting with one another, thus creating individual frustration and large scale inflexibility - or simply time-consuming nonsense. Sociologists have drawn different conclusions from these findings for an adequate conceptualization of organizational coordination, which lead to respectively different consequences for the design of information systems. One way of dealing with inconsistencies in organizations is to uncover misleading or conflicting regulations and especially "concurrencies" (ibid.), and instructing an according re-design of formal structure; most of today's business support software can roughly be located in the line of this approach. But other sociologists claim that the picture of the iron cage does not describe any organizational reality but rather serves as a resource for legitimacy ([14]). Even more, formal structures "dramatically reflect the myths of their institutionalized environments instead of the demands of their work activities" ([31], pp. 431) leading to the consequences of "decreased internal coordination and control ... Structures are decoupled from each other and from ongoing activities. In place of coordination, inspection, and evaluation, a logic of confidence and good faith is employed" (ibid.: 430). Following this description it is obvious that formal structures by no means can serve as a guiding line for computational support systems or the design of MAS.

Sociological approaches that exile formal rationality to the realm of "ceremony" (ibid.) or pure fiction can be seen as corresponding to those approaches which focus on the daily work practices at the shop floor-level, or speaking more generally: on "situated action" ([46]). Most research in Groupware and especially in CSCW (cf. [11]; [38]) follows this micro-level approach, convincingly stating that successful computer support and the design of any software system has to begin which the particular circumstances of every single case. But leaving aside every formal description of organizational coordination comes at a prize: Declaring all of the organizational structures on higher levels of scale (including the organization at large) to be irrelevant leads directly to a strong skepticism about the very sense of modeling (cf. [5]).

This brief discussion seems to end up in a paradoxical situation: Taken together these sociological approaches on the one hand point to the importance of practical rationality and to social pattern that emerge bottom-up, but on the other hand they discourage any attempt to model information systems on principles of organizational coordination. For this reason Les Gasser in his talk at 1990 Seeon Socionics conference recommended concepts of mutual constitution of large scale structures and situated interactions (Giddens and Weick) as the very starting point in DAI and in Socionics. But full-fledged concepts, especially if they try to capture processes of mutual structuration over different levels of scale (see cf. [35]; [44]: 226ff), are in our view too encompassing and difficult to serve for modeling purposes (see Schimank this volume). We choose a less demanding, but expandable approach. The basic idea is that the formal structures are important, but only if they are enacted by the organization's members (and our agents), thus constituting formal roles. The same holds true for practical roles which emerge from shop-floor interactions. We thus state that formal and practical rationality have to be balanced in order to create and maintain a robust and flexible coordination within organizations.

Before proceeding we want to sketch what follows from these considerations for Socionics as a "triangular research program" [28]). We would like to point out that focussing on practical rationality leads to a threefold Socionics challenge. With respect to the "computational reference" our approach plays out the ambiguous meaning of the word "formal". Specifying our approach means to mathematically formalize those practical patterns of interaction which lie beyond the explicit formal descriptions of organizations. The challenge here is to 'formalize the non-formal', and this in our view is a promising way to overcome the paradoxes or dualisms mentioned above, thus contributing to a more balanced blueprint for sociologically grounded MAS - and in the long run also contributing to the development of more successful tools for computer support.

The other way round modeling and computer simulation of practical rationality should also serve as instruments for sociology. In our experience this "sociological reference" of Socionics is especially manifest when it comes to modeling, because there is the necessity of explicit specification. Modeling situated, practical patterns of interaction brings a sociological challenge to the forth because these patterns are often seen as lying beyond theoretical consideration and resting at a micro-level of social life. Thus a tapered concept of practical rationality in the context of organization studies can help to enhance sociological concept-building without falling behind the state of the art. Furthermore simulations can throw light on those practice-based patterns in organizational life that are hard to investigate by usual methods of empirical investigation. An example is the smooth fit of practical roles within organizational units (see below).

The third goal of the Socionics program is to explore or at least asses the consequences that are likely to occur when sociologically grounded MAS are re-entered into human contexts. In the INKA-project this means to explore those new hybrid settings in which practice-based computer agents and skilled human actors have to cooperate. In sociology as in computer science there are no approaches that can avoid the pitfalls of purely theoretical considerations and implementation studies likewise. So the Socionics challenge here is to develop methodological instruments that enable an investigation of these hybrid constellations.

3 Modeling Role Based Agents: Constraint, Scope and Concerted Action

3.1 Modeling Principles

In order to address these challenges the first move is to build computer agents that are capable of behaving in a way that balances formal structures and practice based modes of interaction. So the first question is: What are practical mechanisms of coordination that can be assumed to be relevant for all types of organization? From sociological investigations we know that one way of counteracting formal regulations and especially it's incoherences are negotiations by which the organization's members themselves create a flow of problem solvings for their daily work practices. Relating to sociological concepts (cf. [43]) we define negotiations as a situated mechanism for problem solving for those situations where actors (and our agents) have a high degree of autonomy and at the same time a high degree of mutual dependency. For the organization at large these ongoing negotiations constitute a "negotiation system" (cf. [21],[22]:77-83) that is necessary for the achievement of an overall flexibility of planing and problem solving.

But problem solving via negotiation clearly bears the danger of exaggeration: Permanent negotiations would be very time consuming and frustrating for the organization's members, and it would be dysfunctional from the organization's point of view simply because the members would be kept from getting their job done. So focussing on negotiations leads directly to a second question: How can the dangers of permanent negotiation be avoided without destroying it's advantages? In social life there is a solution for this problem: Every aspect of the negotiation process - the selection of an promising issue, partner and tactics - can be based on the mutual assignment of practical roles, that is patterned expectations of the others and oneself. Practical roles, in other words, can drastically reduce the expenses of negotiating by drawing on generalized expectations.

In the overall picture of our modeling approach the concept of roles serves as a mediating level between the daily negotiations and the structures of the organization at large. The single agents are structured respectively, as figure 1 shows.

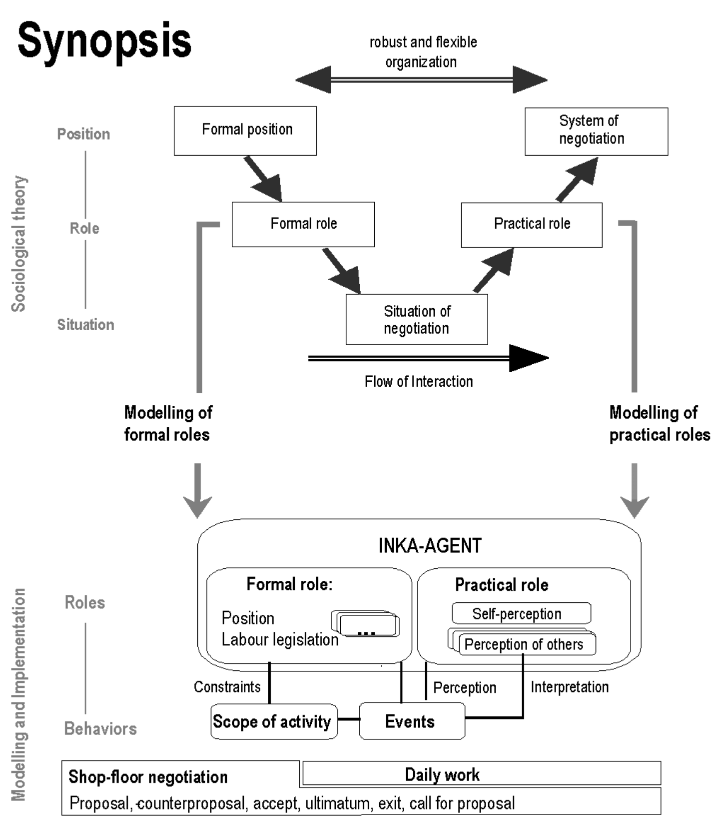

Fig. 1. The modeling approach

The details of the modeling and the concrete data are drawn from our empirical investigation in a specific domain, personal employment planning in hospitals. This domain shows all the characteristics mentioned above: The overlapping of different professions, hierarchies and local styles (cf. [42]) leads to a high degree of formal incoherence in the official shift plans. Therefore the employees negotiate and trade single work shifts aside of the official shift plan, thus making use of the scope the management intentionally leaves blank. These shift negotiations are a daily requirement under rigid time restrictions. Our theoretical assumption is that this works because the negotiations are carried out on the basis of a limited set of practical roles, an assumption that is backed by empirical evidence (for details see [30]).

3.2 Formal Roles as Constraint

Organizations assign formal positions to their members in order to manage and control the internal division of labor. These positions are described explicitly and encompassing, e.g. as job description, rules and regulations etc., which serve as standardized solutions for anticipated problems. But formal positions remain purely abstract if they are not adopted and enacted by the individual members of the organization, thus constituting formal roles. In every developed organization the formal prescriptions are multidimensional in itself. Drawing on [17] we distinguish three necessary aspect of the internal division of labor: first the professional division in the "functional circles" of physicians, nursing staff and administration; second the hierarchical chains of commanding authority and duties; and third the spatial division. We modeled all three aspects as constraints for the internal reasoning processes of the agents, thus limiting the scope of possible individual action in every situation. Additionally we included external prescriptions like e.g. labor time legislation and the salary stages regulated by labor agreement. Technically all of the data are written into a relational data base from which all of the agents derive their information (for deails see [18]).

3.3 Multiple Capital Interests

Agents decide by considering their interests. This can be described mathematically as an expected increase in capital. Organizations, on the other hand, have to equip their members with capital in order to fulfill their positions. Even on the formal side of organizational coordination a purely economic measure of interest would be platonistic (see Schimank this volume). Therefore we modeled interest drawing on Bourdieu's capital sort theory [6, 7] and distinguished economic, social, cultural and organizational capital, the latter transformed into symbolic capital on the practical side of coordination (for details of the computing see [30]). These different types of capital are also important for the valuation of the single shifts that are to be negotiated or traded.

3.4 Practical Roles

In organizations the practical roles themselves emerge from the ongoing flow of situated interaction on the shop-floor level, thus filling the scope the formal prescriptions - weather intentionally or not - leave blank. Situations that are perceived as similar will increase patterned ascriptions, thus generating a relatively stable positioning of types of actors on the practical side of coordination, that is without institutional acts of enforcement like qualification certifications for chefs or sanctions for disobedience etc. A resistance against disappointment gets established that remains relatively stable after a while.

We modeled these pattered perceptions of the interaction partners and of oneself according to the concept of "group figures" [37], which can be observed among lasting informal groups (e.g. juvenile gangs) and also within organizational units (e.g. a bureau or a station in a hospital). The term figure captures the various kinds of leaders, diplomats, mediators, and scapegoats etc. which can be assumed to differ only slightly between different social entities. We termed these patterned expectations "social types". These are described by two classes of parameters: First a type-specific weight in the four capital interests, and second some additional type characteristics (like willingness for compromise, exposal of information, weekend- and shift-variances and willingness for negotiations) that are necessary to cover the differences between the social types. At the moment we are working with a set of nine social types; the profiles (and the names) of the types and their initial capital interests were constructed on the basis of empirical evidence from our domain. These concrete parameters and the initial data are a precondition for the dynamic of interaction to begin. The dynamic of negotiations is described in the next chapter.

4 The IPS Framework: An Architecture for Negotiating Agents

The next step in the incremental development of a sociologically grounded MAS was the specification of an agent architecture for negotiations. Our approach does not only intend to cover the concrete example of negotiations in the PEP domain, but should also serve as a generalized approach to agent negotiations based on the general "belief-desire-intention (BDI) scheme.

In particular we introduce the interconnected concepts of social types, social relations, and strategic behavior. Social types are used in the negotiation process to estimate the partner's attitudes as well as to guide the own behavior. We enrich this negotiation principle by enabling our agents to develop and maintain social relations, so that the agents can develop a tendency to prefer certain agents as negotiation partners. Additionally, agents might tend to be more cooperative towards these partners, what we interpret as altruistic behavior. The social relations change depending on experiences made in the flow of ongoing negotiations.

Observing humans negotiating, it can furthermore be seen that the currently best option is not always proposed. Often this deviation from the optimum is caused by anticipation of middle or long term effects. Introducing this concept as strategic behavior of our agents, we can foster the realism of their negotiations and give them more autonomy in selecting a negotiation step.

Because these concepts are not part of classical approaches to negotiating agents we need a clear localization of where exactly the classical approaches have to be extended. Usually these approaches conceptualize agent negotiations by distinguishing a negotiation object, a negotiation protocol, and a reasoning process [4, 23]. These approaches do not address the negotiation partner explicitly, and the reasoning process itself is not structured at all. These two shortcomings have to be overcome to achieve an adequate integration of the sociological grounded model. Therefore we extended and restructured the classic approach to negotiation modeling and developed the IPS framework [47].

4.1 The IPS as a General BDI-based Architecture

It can be assumed that in our domain, as well as in every negotiation, agents have to take decisions about three important aspects: They have to choose the negotiation issue, the negotiation partner, and the next step in the negotiation process. While these three aspects are interrelated the correlated decision processes are usually separated. This clear separation enables an explicit definition of various interdependencies. Hence we follow a three-layered approach to agent architecture (see figure 2), where the layers are related to the three aspects mentioned above (issue, partner, and step). Initially we defined a simple sequential dependency between the layers, which implies that decisions are taken and withdrawn step-by-step, starting at the issue layer or the at the step layer, respectively.

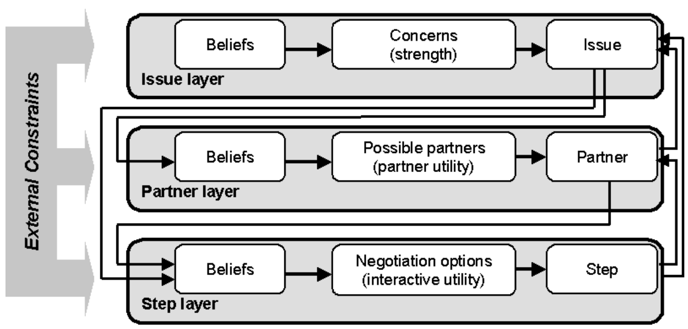

Fig. 2. The IPS framework.

The decision process at each of the three layers is structured according to the BDI approach [41, 34, 16]. Beliefs represent the layer-specific part of the agent's knowledge about the world. Based on these beliefs the agent builds certain desires, that represent preferable choices. In the three layer approach these desires represent concerns the agent wants to negotiate on, or possible partners, or useful steps to achieve the agent's goals. At each layer the desires are ranked according to a function, i.e. strength for concerns at the issue layer, partner utility for promising partners at the partner layer, and interactive utility for negotiation options at the step layer. From all it's desires the agent finally selects an intention, which actually determines the agent's behavior. The agent's enacted intention thus is a specific negotiation step aiming at a particular issue in a negotiation with a particular partner. A combination of layered architectures with BDI approaches has already been described by [50, 9, 16]. These authors frequently used layered architectures to represent different levels of complexity and abstraction. We, contrarily, use the layers to represent different interdependent parts of the complete negotiation process.

4.2 External Constraints

The decision processes at each layer, which are described in more detail in [47], are not only the outcome of an inner calculation of the agents, but also restricted by external constraints. These constraints reduce the number of possible desires to keep the reasoning process simple, e.g. by eliminating unrealistic desires, or by enforcing restrictions specified by the system designer.

The first external constraint limits the possible negotiation objects. We allow our agents to only negotiate exchanges of work shifts they actually possess, i.e. shifts assigned by the administration. Leisure time interest can conflict with this official shift plan. If agents have a leisure time interest that lies above a given threshold they try to initiate negotiations to get rid of such a shift. By this we restrict negotiation issues to exchanges that are related to a particular shift of the initiator. Furthermore in the first version of our system our agents can only negotiate with one other agent at the same time.

These constraints at the issue and partner layer are supplemented by a negotiation protocol that is designed to restrict the step layer. This protocol is structured in three phases: the pre-negotiation phase, the main negotiation phase and the post-negotiation phase. In the pre-negotiation phase, the protocol requires that the initiator of a negotiation - we distinguish between the initiator and the responder - asks a possible partner whether a negotiation is useful, i.e. wheather there has been new information since the last negotiation on the same topic, and whether the other agent is not 'to busy', i.e. is currently not engaged in another negotiation. If these conditions hold then the initiator starts the main negotiation phase by doing the first negotiation step. Following speech act theory we define each step as a performative act combined with a content that can be an exchanged. The performatives for the first step can be a call-for-proposal (CFP), a proposal, or an ultimatum. With the exception of the ultimative performatives agree and cancel, which end every negotiation process, every single negotiation step will be answered by the partner. Every proposal can be followed by an agree, a cancel, a CFP, an ultimatum or a counter-proposal. A CFP is a specific form of strategic behavior in the sense that the partner cannot agree, but only has the chance to formulate a different CFP or proposal, or it can react by an ultimatum or simply by cancelling the negation process. An ultimatum is a very restricied form because it forces a cancel or an agree. If in the end there happens to be an agree the initiator requests the administration for confirmation and then gives the result to the responder. Together with an internal update of the agent's knowledge and relational values this represents the post-negotiation phase.

As described our definition of the negotiation object, the negotiation protocol and the set of possible negotiation partners represent the external constraints to the negotiation model. These external constraints are clearly distinguished from the agent's internal reasoning model which is structured by IPS. Furthermore an initiator conducts a different or at least more complicated reasoning process than the responder, because it is reasonable to assume that the responder's reasoning process is simplified. If the responder is 'not busy' he always can accept a negotiation request. When it comes to the beginning of a negotiation simply sets the negotiation issue and partner to the corresponding values.

4.3 Issue Selection

At the issue layer those shifts that are assigned to an agent according to the shift plan, and those shifts that the agent would like to get rid off, are the desires (or the concerns) of the agent. The agent assigns a strength to each concern. The strength depends on the value of the shift and on the leisure time interest for that particular shift. The agent calculates the value of these shifts by comparing the changes in it's capital stock (composed the four capital sorts) for two cases: if it gets rid of this particular shift or not. As the capital accumulations that can be achieved by future shift exchanges cannot be known in advance, we use shift type specific estimations instead. These estimations result from different characteristics of the shift types, e.g. different manning levels, salary surcharges, and tasks [20, 27]. From all the possible concerns an agent only considers the shifts as as being relevant for intention building which do have a significant leisure time interest. In other words the agents follow a simple strategic behavior. From the remaining concerns the possible[2] concern with maximum strength is selected as the actual intention at the issue layer, hence as issue.

4.4 Partner Selection

The selection of promising peartners for a negotiation can be characterized by three criteria: First these partners should not be excluded from negotiation by formal restrictions; i.g. a nurse can not change a shift with a physician because of the given division of Labor. Second they should be able to take the offered shift, and third there should be no recent 'negative experiences' with this partner, i.g. there has not been an unsuccessful negotiation with them on the same issue. If all this holds true in the next step the reasonable partners for negatiation are ranked by the partner utility, ending up with the possible partner to be chosen as intention at the partner layer. The value of the partner utility is strongly influenced by personal and typified relations likewise, because the agents do not only build 'personal' relations to other agents, but also build relations to social types; these typified relations allow an estimation of promising partners without exhaustive prior experiences with them; it is an advantage of our approach to weight personal and typified relations differently. Additionally every calculation of the partner utility is depending on the partners shift plan. The number and the worth of the possibly exchanged shifts is taken into account, and the latter is given more importance. The value of an exchange itself is based on the difference of the evaluated of capital stocks and the leisure time interest in the shifts to be exchanged.

4.5 Step Selection

At every stage of the main negotiation phase the agents selects a particular next negotiation step. This is done by strategies and tactics that work on a list of negotiation options, which are oriented towards possible exchanges. This list is ranked by an interactive utility, which implements our concept of altruism. We calculate this as the weighted sum of the personal utility and the partner's estimated personal utility. The weight itselfs depends on the social type and on the personal and typified relations.

In our framework a strategy is a set of tactics which can be weighted. The defititions are the following: A tactic generates a single negotiation step by combining a performative with the selected negotiation option. When applying a strategy only those tactics are taken into account that fulfill the following precondition: Tactics

[2] As mentioned above, there are dependencies between the three layers. It may happen that one layer can not find a possible intention for given intentions at the other layers, e.g. it can not find a partner for a certain issue. This leads to the realization that these other intentions are not possible.

without a weight are only considered if the sum of all weights is less than 1. All weights are temporally adjusted so that they sum up to 1. In this case a tactic is chosen randomly, and the probability depends on the weights.

The preconditions of tactics can refer to strategic lines. We have modeled an accept and a cancel line that may change over time. An offer is accepted if the corresponding interactive utility is above the accept line. The negotiation is cancelled if the personal utility of the offered shift is below the cancel line. Because this process is based on two different utility functions we term it "two-scale-based decision making". First simulation runs showed that these definitions are useful, because they avoid situations like the prisoners' dilemma, which can arise when two "excess altruists" - weighting the partner's utility higher than one's own[24] - are negotiating. Currently all implemented tactics follow this principle.

4.6 System Implementation

For the implementation of the INKA system we have evaluated different multi-agent platforms. One important evaluation criteria has been the support of physically distributed agents with individual interfaces. This is necessary for the interactivity experiment (see below). We have decided to use the platform JADE, which supports the development of physically distributed MAS. Because JADE has been developed for application oriented MAS it does not support features that are used in simulations, e.g. data collection and visualization. Simulation oriented systems on the other hand do not support real physical distributedness nor do they offer tools for complex agent architectures and agent communications, e.g. ontology management. In JADE the modeling of communication and the modeling of agent behaviors are explicitly supported. The configuration of the system can be changed dynamically while the system is running, i.e. agents can enter and exit the system or change the position within the network. Our system is completely implemented in Java and thus independent of the operating system.

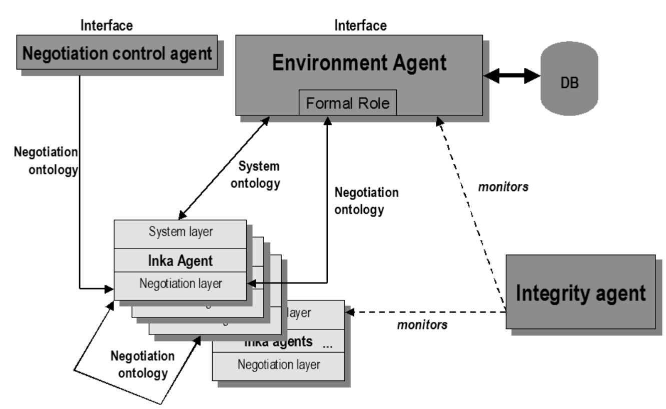

Fig. 3. System architecture for the simulation step.

Figure 3 visualizes the system architecture for the INKA system regarding simulations. The environment agent, as a central element, enables via interfaces the administration and configuration of the single INKA agents and the manipulation of the shift plan. Additionally, the environment agent provides an access point to the system database that contains all relevant data of the scenario (for details see

[27, 18, 30]). Furthermore the environment agent reserves the last authority for final confirmation of any negotiated exchange of shifts, thereby implementing the formal role as a constraint in the INKA system. The integrity agent ensures a safe technical state of the system, especially by coordinating the initialization of the single agents during the start-up process. The negotiation control agent enables us - during system development - to test the layers independently by initiating different types of negotiations: without any guidelines, or with a given issue and/or a given partner.

5 An Integrated Approach for System Development in Socionics

In the previous section we have scretched the basics of our model of negotiating agents. This is only one stage in our overall path to a hybrid system. This path follows the Socionic development cycle as it is shown in figure 4, and constists of four stages. While targeting all of the aspects mentioned in the "Socionics triangle" [28] we arrange these aspects as distinct activities with distinct goals that build on one another. What follows is that from every step the developer might be forced to rephrase the model. In our view it is one important gain of an integrated approach that all stages of development are to be processed by a joint team of computer scientists and sociologists; our experience is that this can put the "going concern" of Socionics [45] on a more structured basis.

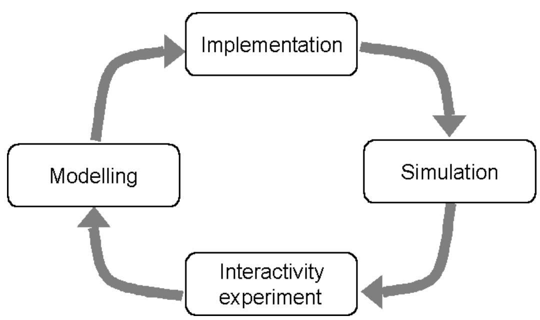

Fig. 4. The socionic development cycle.

The cycle begins with the modeling phase where the principles of agent coordination are derived from sociological theories (see chapter 3) or, as in the case of our project, from additional empirical investigation in the domain. Either way, model building can be seen as the basic activity in Socionics. As in other interdisciplinary enterprises, models in Socionics serve on the one hand as key "mediators" [33] that enables a continuous dialogue between computer science and sociology, but on the other hand working on models produces it's own requirements. It is of special importance that all models should be made complete, not only for reasons of theoretical consistence, but also because they are the starting point for any specification of a simulation model. In our project the translation of the agent-based model into the formalized specifications of the technical MAS has led to a series of model revisions. Thus formalizing practical rationality inevitable comes at the prize of idealizations, but at the end of the day we can see our agents to negotiate enacting practical roles.

In the next stage the simulation model is implemented. Because this stage can be described as a typically software engineering job it is important to apply appropriate methods. In the case of our project the model was implemented in a Java program based on the multi-agent platform JADE. The three-layered architecture of the IPS-framework (see chapter 4) enabled a cyclic implementation, which made it possible to test of each single layer in functional simulations in order to verify that this layer works properly. Again, the results sometimes have made model revisions necessary; i.e. the move from a one-scale-based to the two-scale-based decision process mentioned above was an outcome of such simulations. Beside following an incremental software development methodology, the layered approach also offered the opportunity to observe the behavior of agents with an increasing autonomy: in a first run the issue and partner of the negotiation were given, in a second run only the issue was given, and in a last run the agent's behavior was unconstrained besides the allowance to negotiate.

Simulations, in the picture of the development cycle, can serve three different purposes: As mentioned they first can be used as a check of the basic functionality of the technical system, and second they can serve as a check of the basic assumptions of the model. But in Socionics simulations are mainly used as a special kind of methodology for sociological investigation: an artificial check of sociological hypotheses or an artificial expedition into the foundations of social entities. In the case of our project these expeditions are especially suited because they lead into the realms of practical coordination. This part of the social fabric is hard to tackle by conventional sociological methods, because they remain mostly implicit in daily work practices and are hidden from the actor's perspective as well as from the organizations perspective. By running simulations we especially want to gain insights in those mixing ratios of practical roles that enable or hinder a productive atmosphere, in which problems can be solved smoothly. In the case of our domain this means that negotiation are often successful and do not take much time.

All three purposes of simulation call for evaluation criteria (see chapter 7.1). Because in MAS, especially when they are sociologically grounded, the sheer number of relevant parameters is high, and random processes are likely to occur, in the long run statistical methods to check the significance of simulation results should be developed and applied.

The last stage of the Socionics development cycle is the introduction of human actors into the simulation or the introducing of the MAS into a human social system, thus constituting hybrid sociality. On the technical side this requires an extension of the software system, which has to be a physically distributed MAS, and appropriate interfaces and technical agents have to be introduced. But an examination of the mixing of humans and agents is in the Socionics program not a question of software engineering, but in the first place a question of basic research. In the next chapter we describe our methodological approach for this stage.

6 Design of Interactivity Experiments

Treating the investigation of hybrid settings as one step of it's own in the overall design process for MAS refers to the original Socionics program [28], in which the term hybridization has been used for all processes of re-entering the computer agents into the real-world domains from which their coordination principles were derived - a process that could broadly be labeled as the 'socialization of sociologically grounded agents'. In the resulting settings there is interactivity between technical and human agency, and organizational coordination is based on an entaglement of human and technical sociality (see for these definitions [39]).

In order to make an examination of these new settings possible we started with two considerations. As opposed to philosophical definitions of what is the 'true nature' of an agent's agency we defined the following: If the mutual impact of technical entities as well as their relations to human actors can sensefully be described as social interaction, we will talk of hybrid settings. And as opposed to the often overgeneralized and highly speculative notions of technical agency (eg. in actor-network theory; see [40]) we developed a methodologically controlled approach to an examination of the theoretical problem of hybridization.

6.1 An Experimental Approach

The main issue under discussion is: How can we analyze and examine the interactivity between human agency and technical agency in the early phases of system-development in a methodologically adequate way? Because the changes to be examined are processual in nature and a variety of parameters are involved an experimental procedure seen to be appropriate, where the examination can be restricted to assumed effects of independent variables on one single variable. By this we draw on a narrow understanding of "laboratory experiments" in sociological methodology, as cf. in socio-psychological experiments about group behaviour ([36]:289 ff), which are commonly defined as consisting of three parts:

1. The formulation of precise hypotheses concerning the relationships between the variables involved in the phenomena to be examined.
2. The creation of an examination setting that is to provide almost optimal conditions for testing each hypothesis (cf. [3]: 204ff, [51]: 32ff).
3. The explicit control of the validity of the experimental results, e.g. by introducing control groups or by repetition of series of experiments.

6.2 Hypotheses

In the INKA-project processes of hybridization are to be examined in the context of successful organizational coordination based on practical roles. By this we aim at exploring the 'social chemistry' and it's change through the introduction of sociologically grounded agents. So we focus on patterned variations of social types and their effects on shift negotiations. In an artificial PEP setting it will be examined whether different optimal shift-plans are the outcome of the negotiations of humans and agents. These changes may of course have different time frames. In the following sections we only describe a static interactivity experiment, which is designed for a short-time adaption to an equilibrium of social types.

The coordinational effects that different mixing ratios generate are operationalized with three hypotheses:

1. The precondition of balancing formal rationality by practical roles is that homogenization limits the productive use of social difference, because the scope of activities is smaller. In our domain we assume that resisting homogenization leads to a decrease in poor quality shift-plans. The corresponding hypothesis is: *A non restrictive set of social types achieves better results with regard to the quality of shift-plans then a restrictive set of social types.*

2. It can be assumed that a productive use of social difference does not only depend on the sheer number of types but in the first place on a smooth fit of the types involved. Therefore we are not only interested in the mixing ratio of social types but also in the patterns of distribution of types. The corresponding hypothesis is: *The pattern of distribution is the essential factor for the quality of shift-plans, independent from the social types involved.*
3. Even if agents are modeled on social mechanisms they till are technical craeture and thus differ from humans in nature. Therefore it has to be asumed that there are different stable mixing ratios reflecting various interdependencies. The results depend on the type of negotiation partners. The corresponding hypothesis is: *There are various stable mixing ratios of social types depending on the nature of negotiation partners - if they are only agents, only humans or if they are mixed.*

6.3 Indicators

In experimental runs these hypotheses are ultimately proved by the quality of the new shift-plans that are the result of the negotiation process. But as the quality is a collective aggregate it is by no means clear how this quality can be measured at the outset. Using statistical methods we developed the following indicators to measure a collective quality.

Collective satisfaction with the negotiated shift-plans: Individual satisfaction can be expressed as the percentage of spare time-interest an individual can realize. A collective measure can start with the plausible assumption that the degree of collective satisfaction is high if the majority of staff is satisfied above the above-average satisfaction and at the same time the dispersion of individual satisfaction is small. We weigh the results on an ordinal-scale from 1 to 10. A shift-plan that produces a high mean and a small dispersion of satisfaction is scored as the best result.

Frustration caused by the negotiated shift-plans: The individual interest in efficient shift negotiations is defined in negative terms. The measure is the individual frustration with a specific negotiation in relation to all it's negotiations. The degree of collective frustration can be defined to be small if the average of the staff shows little frustration and the dispersion of individual frustrations is small. In statistical terms the best result is composed of a small mean and a small dispersion of individual frustrations.

Organizational perspective to negotiated shift-plans: The organization at large has a strong interest in a minimum of rotation of the employers concerning the different shift types (early-, late- and night-shift) because in case of accident every employee needs to know the specific work-flows of every shift in order to get all the incidental jobs done. We calculate this minimal organizational request in the following way: An individual employee who covers all the different shift types in the common accounting period gets the value 1. If he fails to do this he gets the value 0, what means he is sanctioned by the organization. For the collective measure we defined different thresholds. If only 75 precent or less of the staff fulfill this request of minimal rotation the whole shift plan will be dropped by the organization. Such a shift-plan gets the value 0 and he will simply be refused by the organization whatever the values for satisfaction and frustration are. If 75–89 percent of the staff fulfill the rotation conditions we multiply with the 0,8. In the optimal case of 90–100 percent we multiply with 1.

The collective results of these three indicators are calculated in the following way:
(Score satisfaction + score frustration) x value of organizational perspective = score for the quality of shift plan.
Initial computations show that this mode of statistical evaluation offers good distinctive features for a measurement of the quality of shift-plans based on the constellation of social types.

6.4 Experimental Setting

Because under experimental conditions the test-persons can concentrate solely on negotiation task, these negotiations will lead to rapid results. Therefore a considerable amount of single negotiations with different starting conditions and different exercises can be run in relatively short time (we plan a two day experiment). The concrete setting can be descibed as follows: The test-persons sitting isolated at computers are in a black box situation because they do not know if the other negotiation partners are humans or agents. Every test-person gets specific negotiation jobs and a list of the social types of the other participants involved. For put this experimental situation to work we have to choose professionals working in a hospital a test-persons, because they need to have experience with the various social types and their behaviours.

For the analysis of the experiment we can draw on two different data sources: the negotiation protocols which are compiled by the computer, and the new shift-plans that are resulting from negotiation. As we are only interested in the results of negotiations these data are sufficient for a check of hypothesis and an interpretation with the indicators mentioned above.

6.5 Ensuring the Validity of Experimental Results

Experiments in the social sciences call for internal validation criteria. We adopt the proposal of a "pretest-posttest control group design" ([13]: 248). The pretest has to assure that the measured effects are not only an outcome of the instrument (or the experimental setting) itself; therefore running the whole procedure without agents is one good test. Additionally we systematically compose control groups of humans and agents likewise and deploy them in every phase of the experiment.

6.6 Outline of Dynamic Interactivity Experiments

A second type of interactivity experiments is designed for an examination of dynamic changes that arise from hybridization over a longer period. As with any introduction of a technical system in an organization the introduction of our MAS can be expected to cause organizational changes. We are focussing on changes on two different levels of scale: On the micro level we will analyze the emergence of negotiation routines from interaction and from interactivity; on the level of the organization at large we will analyze the emergence of coalitions and "communities of practice" in the overall context of organizational learning.

As the specification of these experiments is future work we will present the general outline of the questions to be examined in the following chapter. Extending the experimental approach to dynamic processes calls for a different setting and duration of the experiments. It ill be necessary to bring the system to the real world-context of the test-persons, who will daily negotiate via or with the MAS for at least one month.

7 Extending the Approach: Future Work

7.1 Evaluation and Generalized Criteria for System Evaluation and System Quality

As mentioned in chapter 5 the Socionics development cycle itself involves several evaluation steps which call for criteria of measurement and quality. The development of criteria that can guide a judgement - or at least an assessment - of the appropriateness of a MAS becomes even more important when the systems and architectures of the Socionics program are to be compared with one another, or with MAS or negotiation systems that stem from a different background. As this is part of further work we cannot present a comprehensive proposal for these questions, but we want to address three areas which in our view are important for the Socionics enterprise at large.

As all MAS (including those we build in Socionics) derive their functionality from distribution, that is the coordinated interaction of individual agents, the question is: What kind of criteria is adaequate for distributed design? One possible criterion for the quality of distributed solutions could be the degree of individual achievement of preferences in the collective solution. If this is a promising starting point MAS are faced with the same problem as any social decision making process that tries to achieve a best solution for a collective. Taking an individualistic approach the collective preferences should be something like an aggregation of the individual preferences. But it is unclear what aggregation means and how an optimal or even a better collective solution could be identified. Arrow's theorem (see [25, 15]) states the impossibility of an aggregated solution that fulfills the following conditions:

- all individual preferences are considered;
- the Pareto principle holds (if every agent prefers an alternative then the collective choice does the same);
- the solution is independent of irrelevant alternatives; and
- there is no dictatorship.

Every proposed evaluation criteria, such as Pareto optimality, classic and extended utilitaristic optima, or the less-known "fair allocation" criterion[3] violates one or more of intuitive conditions mentioned above. Within the context of our project we will evaluate whether these criteria can be extended to distributed solutions. The background is that, in contrast to the use of a single utility value as in classical economic approaches, we implemented from the very beginning multi-dimensional utilities (Bourdieu's capital sort theory).

A second area of questions arises when it comes to an evaluation of the scalability of our system. Here are several dimensions involved: How does the system react to an increase of agents or to an increase of social types? How does it react to an increase of the internal capabilities of the agents, e.g. increased learning capabilities and more complex negotiation strategies and tactics? How does it react to an increase

[3] Pareto optimality plus there is no envy of an other agent's share of the allocation.

of autonomy of the agents, and as an extreme to the introduction of human actors (hybridization)? Will it be able to cope with the concurrencies of the human decision processes, and with the introduction of random processes? A first step to tackle these questions is to test whether the system will remain technically stable , i.e. the timing of the system is appropriate and the system itself works correct.

A third point is to develop a way to compare the different architectural solution that are used in the different Socionics projects. These architectures are tailored for different theoretical questions and different domains. Could it be possible to gain insights in the overall quality of the solutions by porting one architecture into the setting of an other project? And shouldn't there be an effort to develop standard examples or even a Socionics testbed, that would allow a comparison of the different architectural solutions proposed by the different projects?

7.2 Enhancing Practical Agency on the Micro-Level: Introducing Case-Based Reasoning and Genetic Algorithms

On the micro-level of our approach the agents' enactment of practical roles would be incomplete without the capability of interaction based on experience, that is without the capabilities of learning and following routines. We are trying to achieve this by introducing an altered version of Case-Based Reasoning (CBR). CBR [1, 26] is, generally speaking, a structured approach to machine learning that stores and provides former experiences as single cases, and the usage of know cases as a solution for new, but resembling situations where the solution is not evident. Those cases with the most similar problems are retrieved from the case-base and their positive solutions are used to solve the current problem. In the context of our project we want to enable our agents to anticipate negotiation results, to provide them with more efficient processes for selecting a partner and a strategy, and especially to enable them to develop routines.

The CBR approach can be used whenever a new situation arises in the flow of negotiation. Because the problematic part of our cases is the appropriate characterization of the current situation, which includes (among other parameters) a promising partner, the capital stock, the social types of the other agents and an evaluation of their shift plans, the solution contains a sequence of negotiation steps taken in the former negotiation. This sequence constitutes a complete strategy. In any situation there are two possible outcomes of the check of the case-base:

- If there is a very similar positive case, i.e. a case with a successful negotiation, the solution of this case is applied to the current negotiation. That means the complete strategy is used as a negotiation routine.
- If no similar cases are found, which means there is no prior experience resembling the current situation, the agent will act step by step according to the IPS implementation as described in chapter 4. In these cases the negotiation leads to a new experience, that extends the case-base.

We address a further extension of this approach by combining sociological concepts on establishing routines, as well as clustering approaches from computer science. By this we aim at enhancing the agents ability to generalize from many similar specific experiences. The overall idea of using CBR in the INKA system is presented in [18].

But using CBR also creates a severe problem, because the search for a promising strategy is a purely local search. Even the adaptation used for similar cases and the reasoning without CBR, which includes an element of randomness in selecting tactics, still keeps close to the strategies known before. But as we know from the sociology of organizations the restriction to routines disables any new perception of situations, thus ending up in "lock-in" effects, a common problem in social life. This can only be avoided by choosing a completely new solution from time to time, thus counterbalancing the conservative tendency of CBR by an approach for global search. We address this aspect by integrating genetic algorithms (GA) [19, 32]. GAs construct new solutions by combining parts of successful solutions and by randomly modifying parts of solutions, while unsuccessful solutions are eliminated. In our context GAs can be used for reconstructing strategies and tactics when reasoning without CBR. They can also be utilized in conjunction with CBR, e.g. they can combine similar positive cases to create another potentially positive case. The ultimate goal of our approach is to combine CBR and GA models to a technical realization of routines, as well as an useful deviation from routine.

7.3 Enhancing Practical Agency on the Organizational Level: Introducing Organizational Learning

The re-entry of our sociologically grounded MAS into the organization can be viewed as a special type of organizational learning, because hybridization leads to a dynamic re-balancing of formal structure and practical rationality in the organization at large. The practical side of this re-balancing process can be targeted with two categories from sociology on two different levels of scale: the emergence of coalitions and the emergence of "communities of practice".

Coalitions can drastically reduce the costs of negotiating by delegating parts of the individual interests to a group. The dynamic interactivity experiment (see chapter 6.6) is planned to cover a time-span long enough to allow an examination of coalitions emerging.[4] In the context of the INKA-project the main questions are: Does the introduction of the MAS result in hybrid coalitions of humans and agents? And what does this mean for the efficiency and flexibility of the organization's PEP procedures?

For an overall picture of organizational coordination one aspect of practice based coalition building is of special interest: the emergence of "communities of practice" (cf. [48, 49]) which are composed of the members of the organization who care collectively about practical problems of the organization, without having the official duty to do so. In our context this practical problem is the efficiency and fairness of the distribution of shifts. We focus on the question: Does the introduction of the MAS result in hybrid communities, and what are the organizational consequences of this strengthening of practical coordination?

These two categories and the corresponding questions require additional conceptual work, drawing on concepts from the sociology of organizations and from science and technology studies. And they have to be translated into concrete hypotheses and indicators in order to enable a methodologically controlled examination. On this basis it will be possible to achieve a full-fledged approach to the investigation of hybridization processes, thus closing our version of the Socionics development cycle.

[4] Patterns of coalition building are also of great interest for the modeling and validation of complex decision making in computer science; see cf. [25].

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